

# Collaborative Health Resources Management Model

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## Abstract

In Chile, rural population faces long access times to specialized health services, as these tend to be concentrated in regional capitals. Against this background, the present study proposes the establishment of a Collaborative Health Resources Management Model, based on the practice of sharing hospital resources between medical centers, allowing daily transfers of doctors and medical equipment within a hospital network. The objective is to meet local demand and increase rural accessibility to healthcare, in terms of reducing patient transfers between hospitals and access times. To compare the current and proposed scenarios, an Integer Optimization Model with a Network Structure is formulated. The case study is focused on urology specialty in Zona del Reloncaví, a rural area located in southern Chile, on which it is concluded that allowing the mobility of hospital resources, specifically doctors and equipment, is optimal, as the average number of patient transfers and the average access time are reduced by 95.6% and 83%, respectively. By applying this model, hospitals are able to stretch their limited capital budgets by jointly purchasing equipment, providing network-wide access to resources needed for expanding healthcare accessibility.

## Keywords

Healthcare, Logistics, Accessibility, and Collaborative economy.

## 1. Introduction

Over the last years, disparities in the population's spatial access to health services have become a global issue, being even more challenging in developing countries, such as Chile (Van Doorslaer et al. 2007; Peters et al. 2008; Fábrega, 2013). Vaccaro (2011) defines spatial accessibility to health care as the relative ease of health services to be utilized by the population, depending on the geographic structure over which they are distributed and the limitations it imposes.

Compared to the urban population, the rural one often has poor access to health services, largely due to impediments to travel and availability of services (Marmot 2005). The challenge is exacerbated when considering that health services and population demand are hardly equally distributed (Luo et al. 2009). In fact, geographic disparities in access to health care exist within rural areas themselves, where lower accessibility is often associated with rural areas

that are farther away from the nearest urban area, especially due to the unequal distribution of population and services (Apparicio 2017).

In Chile, this problem has been identified mainly in the rural sectors of the southernmost areas of the country. Its population faces long access times for specialized health services, considering that these are concentrated in the regional capitals, thus imposing a forced displacement of patients. This is the case of Zona del Reloncaví, located in Región de Los Lagos, where health facilities in isolated sectors present a shortage of doctors and machines to attend their patients, meaning that patients must move to the hospital of Puerto Montt, the regional capital, in order to be treated, with all the limitations and costs that this displacement imposes (Instituto Nacional de Derechos Humanos 2016).

The Pan American Health Organization (PAHO) has referred to fragmentation, lack of efficiency and commoditization of health in Latin America as the main causes of rural lack of spatial accessibility to health services in the region (PAHO 2010). In view of this diagnosis, the Ministry of Health in Chile (MINSAL) has promoted the creation of Integrated Health Services Networks (IHSN), following PAHO's recommendations. The establishment of IHSN aims to change the management focus of health resources, through the integration and coordination between hospitals in a health network (PAHO 2010). However, analyzing the implementation's proposals for IHSN in Chile, it is concluded that they do not establish a strategy of decentralization of health resources from the regional capitals, but rather accentuate the concentration of specialized health resources in these cities (MINSAL 2018).

## 1.1 Objectives

Based on the mentioned background, the main objective is to study how to plan a Collaborative Health Resources Management Model (CHRMM) in Zona del Reloncaví, through the practice of sharing hospital resources among its health facilities. Thereby, the objective is to quantify the potential benefits of this practice, in terms of the spatial accessibility of the rural population to the healthcare system and the level of service offered by hospitals, so as to consolidate this proposal as an effective implementation of IHSN in Chile and, thus, promote the paradigm shift to people-centered health approach.

The paper is structured as follows. In Section 2, literature review regarding physical accessibility to the healthcare system, collaborative purchasing in healthcare, and humanitarian logistics is presented. Thereafter, in Section 3, the methodology is explained, followed by the explanation of the data collection process in Section 4. Next, in Section 5, numerical and graphical results, along with possible improvements are shown. Finally, findings and recommendations are summarized in Section 6.

## 2. Literature Review

### 2.1 Physical Accessibility to Healthcare System

Lately, the concept of physical accessibility to the healthcare system has acquired significant relevance as a social indicator, especially in developing countries (Kumagai and Wachs 1973), as Chile. The reason behind its importance lies on the fact that the degree of accessibility is one of the most significant elements for measuring the efficiency of a health care system (Fatih 2013). Some have measured physical accessibility using a Geographic Information System (GIS) in Honduras, Bangladesh and Pakistan (Aguilar et al. 2004; Sarani 2011; Hafeez et al. 2019).

### 2.2 Collaborative Purchasing in Healthcare

When implementing the practice of sharing medical equipment between hospitals in a health network, there are two options: each hospital independently buys its equipment and shares it, or the network, as a purchasing group, collaboratively purchases its equipment. During the last years, collaborative purchasing (CP) has been widely used in different areas, such as healthcare, schools and governments, with the objective of lowering costs and reaching other organizational goals. In fact, CP has been mostly practiced in the public sector in healthcare (Nollet and Beaulieu 2005; Kusters and Versendaal 2011; Gobbi and Hsuan 2015).

In order to effectively apply CP, it requires important efforts in coordinating the different actors involved in the process. Nollet and Beaulieu (2005) identified many factors that impact the development of purchasing groups in

healthcare. The most important ones include payers' intervention, nature of benefits, procurement strategy, nature of relationship with suppliers, structure and resources. Moreover, Gobbi and Hsuan (2015) identified other key factors for CP, including developing mutual trust and reach consensus within the purchasing group, promoting communication between the different stakeholders and aiming to simplicity in the specification and evaluation process.

The study carried out by Gobbi and Hsuan (2015), shows that the benefits of CP not only include money savings, it also improves the quality of the healthcare service provided to patients. In spite of its many benefits, CP also has many impediments for its application. Kusters and Versendaal (2011), by conducting a survey between February and March 2010 including Dutch hospitals and procurement managers, identified several impediments related to costs, control and flexibility, and proposed an IT program to for solve them.

## 2.3 Humanitarian Logistics

The transportation of different type of resources for giving a solution to lack of accessibility has already been assessed in Humanitarian Logistics (HL). It is the process of planning, implementing, and controlling the flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people (Hall et al. 2011). In terms of this study, increasing rural patients' physical accessibility is considered to be alleviating a suffering.

Nowadays, technology is a crucial element in healthcare. Especially, in logistics. For instance, unmanned aerial vehicles (UAV) have been used to transfer blood products, search and rescue missions, and for collecting data as radiation levels (Anbaroğlu 2019; Amukele 2019). In the past years, technology has gained even more relevance because of its utility in HL and due to the importance of information systems for its success (Özdamar et al. 2015). In fact, the development of information technology is crucial for providing visibility to the multiple actors in the supply chain of relief items and is a huge step forward for HL (Davidson, 2006). For example, technology, such as drones, has been used as a response for disasters and relief operations (Chowdhury et al. 2017; Pathak et al. 2019).

## 3. Methods

This study focuses on an area located in southern Chile, named Zona del Reloncaví. According to the Chilean Census Data, it has a population of 464,292 inhabitants (Instituto Nacional de Estadística 2017). Figure 1 shows its location, along with its region's capital city, Puerto Montt, and two other cities, Calbuco and Frutillar. For simplicity, this article considers the health network composed by the hospitals of the three mentioned cities. Furthermore, it only studies the demand for urology procedures, considering that it uses essential equipment that is easy to transport and share between hospitals, unlike other specialties that use intrinsically sensitive machines.

The picked procedure for this study consists of four stages, as shown in Figure 2. For each stage, the output of the previous one serves as its input. The first stage consists in elaborating an Integer Optimization model, with a network structure. The second stage looks for historical information about medical attentions and demand for urology procedures in the chosen location. The following stage uses Python Gurobi to solve different instances for the model, based on the previously collected data. Finally, the last stage carries out a results analysis.

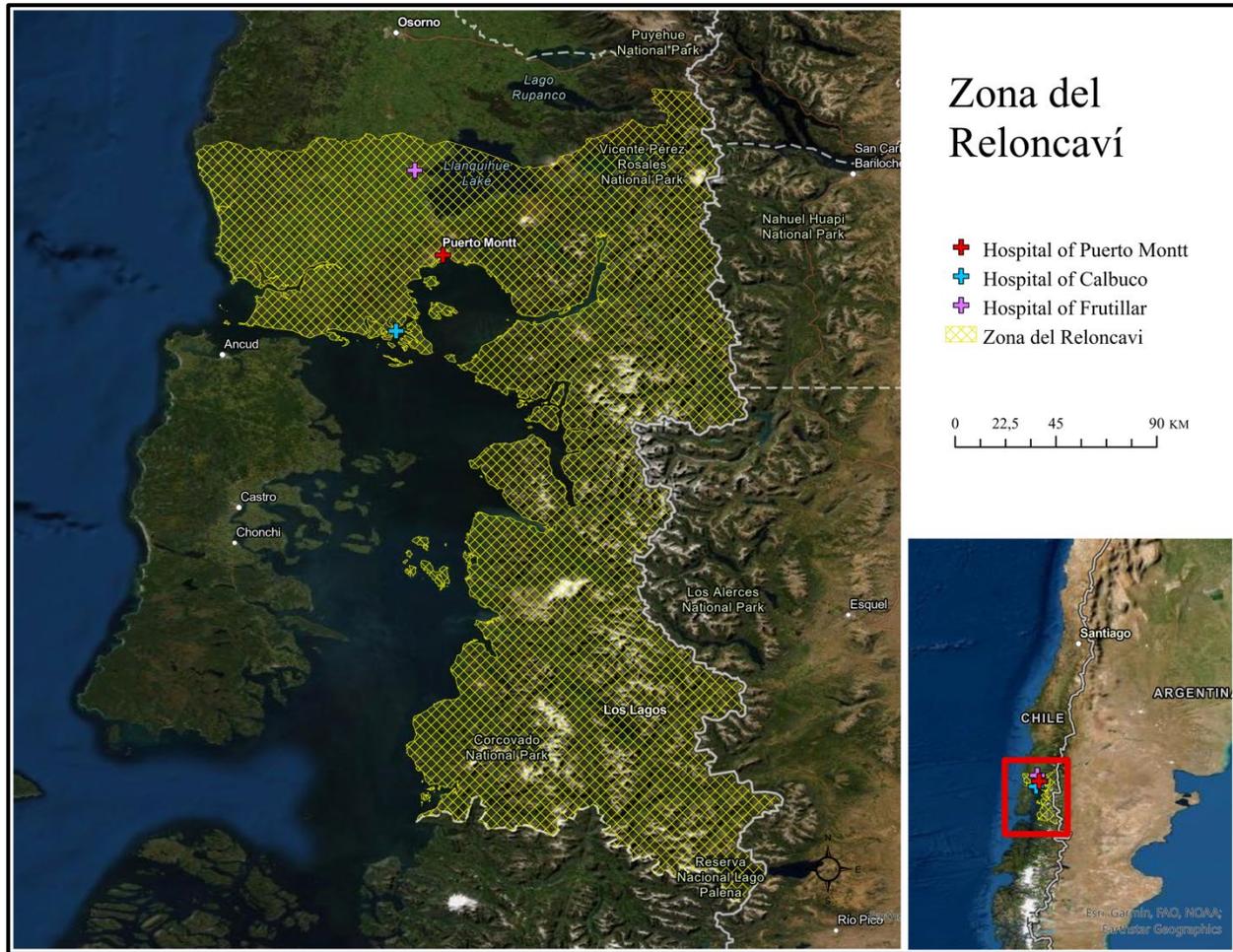


Figure 1. Map of Zona del Reloncaví. The area marked in yellow represents Zona del Reloncaví, located in the south of Chile. Also, the hospitals within the chosen network for the study are marked with a cross. Puerto Montt’s hospital is marked with a red cross, Calbuco’s with a light blue cross and Frutillar’s with a pink cross.



Figure 2. Methodology’s scheme. The four steps considered for this study are shown inside the boxes.

### 3.1 Problem Statement

The problem consists in planning the distribution of patients, doctors and medical equipment in the chosen health network for a time horizon of one month, with the objective of meeting daily demand, while minimizing access times and patients’ transfers. Access time refers to the time from the moment the patient arrives at a hospital until the moment he/she is treated. Each hospital has its own demand, and resources, i.e., doctors and medical equipment. There exists the possibility of transferring patients and resources between hospitals.

The assumptions considered are:

1. The number of doctors and medical equipment is fixed throughout the time periods.
2. The average daily demand at each hospital for urology medical attentions is known.
3. Transfers take place at the end of the day and reach their destination at the beginning of the next day.

4. Doctors and medical equipment are available as soon as they reach their destination.
5. Transportation costs are linear in the quantity transported.
6. There is infinite capacity for patients, doctors and medical equipment at each hospital.
7. There is FIFO<sup>1</sup> patient priority.
8. All patients can travel from their houses to their nearest hospital.

### 3.2 Model's Formulation

The model considers the following sets and parameters.

#### Sets

$H$  = hospitals.

$P$  = time periods.

#### Parameters

$D_{it}$  = demand at the beginning of period  $t \in T$  at hospital  $i \in H$ .

$R$  = number of patients a doctor can treat per day.

$I_i^D$  = initial number of doctors at hospital  $i \in H$ .

$I_i^M$  = initial number of medical equipment at hospital  $i \in H$ .

$C_{ij}^P$  = unitary transportation cost for patients between hospital  $i \in H$  and hospital  $j \in H$ .

$C_{ij}^D$  = unitary transportation cost for doctors between hospital  $i \in H$  and hospital  $j \in H$ .

$C_{ij}^M$  = unitary transportation cost for medical equipment between hospital  $i \in H$  and hospital  $j \in H$ .

The main decision of this program is the daily number of transfers of patients, doctors and medical equipment between hospitals. To address this, the model's variables are explained below.

#### Variables

$x_{ijt} \in \mathbb{Z}^+$  = transfers of patients from hospital  $i \in H$  to hospital  $j \in H$  at the end of period  $t \in T$ .

$y_{ijt} \in \mathbb{Z}^+$  = transfers of doctors from hospital  $i \in H$  to hospital  $j \in H$  at the end of period  $t \in T$ .

$z_{ijt} \in \mathbb{Z}^+$  = transfers of medical equipment from hospital  $i \in H$  to hospital  $j \in H$  at the end of period  $t \in T$ .

$e_{it} \in \mathbb{Z}^+$  = amount of exits of treated patients in hospital  $i \in H$  at the end of period  $t \in T$ .

$s_{it}^P \in \mathbb{Z}^+$  = inventory of patients in hospital  $i \in H$  at the beginning of period  $t \in T$ .

$s_{it}^D \in \mathbb{Z}^+$  = inventory of doctors in hospital  $i \in H$  at the beginning of period  $t \in T$ .

$s_{it}^M \in \mathbb{Z}^+$  = inventory of medical equipment in hospital  $i \in H$  at the beginning of period  $t \in T$ .

$w_{td} \in \mathbb{Z}^+$  = number of patients that waited more than  $d \in T$  periods to be treated, evaluating at period  $t \in T: t > d$ .

The proposed model is as follows:

$$\min \sum_{d \in T} \sum_{t \in T: t > d} w_{td} + \sum_{i \in H} \sum_{j \in H} \sum_{t \in T} (C_{ij}^P \cdot x_{ijt} + C_{ij}^D \cdot y_{ijt} + C_{ij}^M \cdot z_{ijt}) \quad (1)$$

$$s_{it}^P = s_{i(t-1)}^P + D_{it} - \sum_{j \in H} (x_{ij(t-1)} - x_{ji(t-1)}) - e_{i(t-1)} \quad \forall i \in H, \forall t \in \{2, \dots, |T|\} \quad (2)$$

$$s_{i1}^P = D_{i1} \quad \forall i \in H \quad (3)$$

$$s_{it}^D = s_{i(t-1)}^D - \sum_{j \in H} (y_{ij(t-1)} - y_{ji(t-1)}) \quad \forall i \in H, \forall t \in \{2, \dots, |T|\} \quad (4)$$

$$s_{i1}^D = I_i^D \quad \forall i \in H \quad (5)$$

$$\sum_{i \in H} s_{it}^D = \sum_{i \in H} I_i^D \quad \forall t \in T \quad (6)$$

<sup>1</sup> First-in, first-out.

$$s_{it}^M = s_{i(t-1)}^M - \sum_{j \in H} (z_{ij(t-1)} - z_{ji(t-1)}) \quad \forall i \in H, \forall t \in \{2, \dots, |T|\} \quad (7)$$

$$s_{i1}^M = I_i^M \quad \forall i \in H \quad (8)$$

$$\sum_{i \in H} s_{it}^M = \sum_{i \in H} I_i^M \quad \forall t \in T \quad (9)$$

$$x_{ii|T|} = 0 \quad \forall i \in H \quad (10)$$

$$y_{ii|T|} = 0 \quad \forall i \in H \quad (11)$$

$$z_{ii|T|} = 0 \quad \forall i \in H \quad (12)$$

$$\sum_{j \in H} x_{ijt} \leq s_{it}^P - e_{it} \quad \forall i \in H, \forall t \in T \quad (13)$$

$$\sum_{j \in H} y_{ijt} \leq s_{it}^D \quad \forall i \in H, \forall t \in T \quad (14)$$

$$\sum_{j \in H} z_{ijt} \leq s_{it}^M \quad \forall i \in H, \forall t \in T \quad (15)$$

$$e_{it} \leq s_{it}^P \quad \forall i \in H, \forall t \in T \quad (16)$$

$$e_{it} \leq R \cdot s_{it}^D \quad \forall i \in H, \forall t \in T \quad (17)$$

$$e_{it} \leq R \cdot s_{it}^M \quad \forall i \in H, \forall t \in T \quad (18)$$

$$w_{td} = \sum_{i \in H} D_{i(t-d)} - \sum_{i \in H} \sum_{k=t-d}^{t-1} e_{ik} \quad \forall t \in T \quad (19)$$

$$y_{ijt} = 0 \quad \forall i \in H, \forall j \in H, \forall t \in T \quad (20)$$

$$z_{ijt} = 0 \quad \forall i \in H, \forall j \in H, \forall t \in T \quad (21)$$

In the model, the objective function (1) is to minimize patients' access times and transfers of patients, doctors and medical equipment between hospitals. Constraints (2)-(3), (4)-(5)-(6) and (7)-(8)-(9) establish the conservation flow for patients, doctors and medical equipment, respectively. Constraints (10), (11) and (12) forbid transfers on the last period of time. Constraints (13), (14) and (15) define upper bounds for the three types of transfers: patients, doctors and medical equipment, respectively. Constraints (16), (17) and (18) define the amount of exits of treated patients at each hospital as the minimum between the number of patients, the number of doctors' appointments and the number of appointments in which medical equipment is used. Constraints (19) define the variable that represents the number of patients that waited more than  $d \in T$  periods to be treated. Finally, constraints (20) and (21), when activated, forbid doctors and medical equipment's movements between hospitals.

#### 4. Data Collection

For determining the daily demand for health services at each hospital, specifically for urology in Zona del Reloncaví, monthly statistical summaries are used. Each facility periodically sends this information to MINSAL, which are then published on the web platform of the Department of Health Statistics and Information. In order to obtain a representative sample of the structure of the demand in this area, the monthly average of urology attendances in June, between the years 2017 and 2020, is calculated. It should be noted that all urology procedures are currently performed

at the Puerto Montt's Hospital, so the estimation of demand at each city in Zona del Reloncaví is based on the proportion of its resident population (see Table 1).

Table 1. Estimated monthly demand for urology procedures and population for each city of the hospital network.

City	Population	Demand
Puerto Montt	298,617	1,934
Calbuco	38,153	247
Frutillar	19,740	128

On the other hand, for determining the supply of urologists, the Active Transparency Portal of the Puerto Montt's Hospital is used, considering that it is the only health center that offers this specialty in all Zona del Reloncaví (see Table 2). This platform has details regarding contract personnel, staff, and those subject to the Labor Code, including their working hours. Thus, it is estimated that a doctor can handle 10 medical appointments per day.

Table 2. Daily supply of urologists and medical equipment for each city of the hospital network.

City	Number of Doctors	Number of Equipment
Puerto Montt	7	7
Calbuco	0	0
Frutillar	0	0

As for travel costs for patients, doctors and equipment between the three modeled hospitals, these are defined based on Google Maps travel time tool, considering displacement along the main connecting road in the sector, named Ruta 5 Sur.

## 5. Results and Discussion

For the purpose of quantifying and analyzing the potential benefits of sharing hospital resources between health facilities, the main results of the simulated implementation of the proposed CHRMM are presented below. Given the characteristics of this model, a comparative analysis is made between two simulated scenarios: [1] without transfers of doctors and machines; [2] with transfers of doctors and machines. Scenario [1] activates constraints (20) and (21) of the model presented in Section 3.2, while scenario [2] deactivates them.

### 5.1 Experiments

A set of 100 instances is solved for both scenarios. Experiments were carried out on a computer with a 2-core Intel processor, 1.2 GHz CPU and 8 GB of RAM. The experiments include the aforementioned health network, considering the information collected in the previous methodology's step. Only one specialty is studied, urology. Also, the experiments consider one type of medical equipment and assume that demand for urology attentions follows a Poisson distribution.

### 5.2 Numerical Results

It should be noted that in both scenarios all patients are treated. However, access times between them change. In the second one, access times are reduced by 83%. In scenario 1, 1,841 patients have to wait one day to be treated, while in scenario 2, 303 patients wait one day. In both cases, the rest of the patients are treated the same day of their arrival. Considering that nowadays rural population faces longer access times for specialized health services compared to urban population, these results show that the implementation of the proposed CHRMM reduces this disparity by decreasing overall access times, thus improving the network's level of service.

Table 3 presents the average patient, doctor and medical equipment transfers between the hospitals in the selected health network for the two simulated scenarios. In scenario 1, the demand within rural locations cannot be met in those areas, generating forced transfers of patients from rural areas to Puerto Montt’s hospital. On the contrary, the implementation of the proposed model in scenario 2 allows satisfying demand in the patients' local areas, hence reducing the average number of patient transfers from rural areas of Zona del Reloncaví to Puerto Montt’s Hospital by 95.6%. Regarding the transfers of doctors and medical equipment in scenario 2, it is observed that, in general, the implementation of the CHRMM promotes the transfer of doctors and machines on four occasions: both from Puerto Montt to Calbuco and from Puerto Montt to Frutillar. Then, doctors and machines operate according to demand, to finally return 75% of the hospital resources to Puerto Montt, while the remaining 25% is redistributed between the hospitals in Calbuco and Frutillar, according to their requirements. Based on the mentioned results, it can be inferred that the implementation of the suggested model increases rural population’s spatial accessibility to healthcare systems.

Table 3. Average daily movements of patients and hospital resources between the hospitals of the defined network, in the simulated scenarios (forbidding and allowing transfers, respectively), within the studied time horizon.

Origin	Destiny	WITHOUT TRANSFERS			WITH TRANSFERS		
		Patients	Doctors	Machines	Patients	Doctors	Machines
Puerto Montt	Calbuco	0	0	0	4	4	4
Puerto Montt	Frutillar	0	0	0	1	4	4
Calbuco	Puerto Montt	230	0	0	3	3	3
Calbuco	Frutillar	0	0	0	1	1	1
Frutillar	Puerto Montt	92	0	0	3	3	3
Frutillar	Calbuco	0	0	0	2	1	1

Likewise, Table 4 shows that the overall exit rate in both scenarios is the same. However, in scenario 1 all exits take place in Puerto Montt’s hospital, considering that Calbuco and Frutillar do not have the required hospital resources for urology treatments. On the other hand, in scenario 2, Calbuco is now able to treat, on average, 8 patients per day and Frutillar, on average, 3 patients per day requiring urology procedures. This is possible at the expense of the reduction in the number of average daily exits in Puerto Montt’s hospital, from 73 to 62. Consequently, it can be inferred that the implementation of the CHRMM has an impact on the redistribution of patient exits, strengthening healthcare in their places of origin.

Table 4. Average daily patient exits in the simulation scenarios within the studied time horizon (forbidding and allowing transfers, respectively) for each hospital in the network. An exit represents a patient that was treated.

Hospital	Exits WITHOUT TRANSFERS	Exits WITH TRANSFERS
Puerto Montt	73	62
Calbuco	0	8
Frutillar	0	3

### 5.3 Graphical Results

For scenario 2, Figure 3 and Figure 4 depict the inventory levels of patients, and of doctors and medical equipment, respectively. It should be noted that doctors and medical equipment’s inventory levels at each hospital are exactly the same, throughout the entire month. That result is logical since for attending one patient, exactly one doctor and one medical equipment are needed. Also, considering that Puerto Montt holds a higher demand for urology procedures, its hospital has the highest inventory of patients, doctors and medical equipment throughout the studied time horizon. Finally, it is inferred that the inventories of doctors and medical equipment tend to adjust to the inventories of patients, in order to reduce the last one.

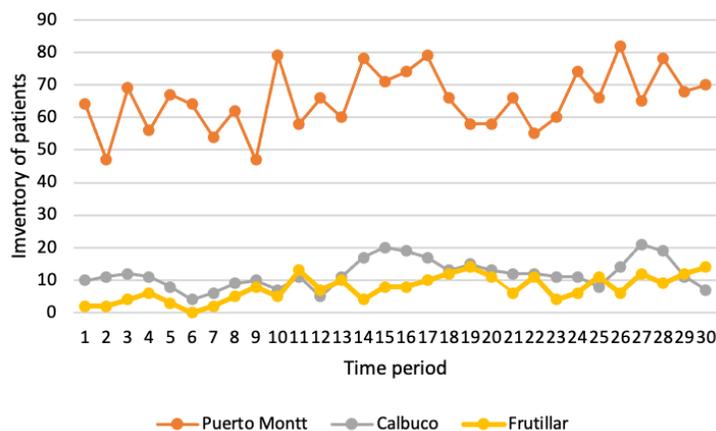


Figure 3. Inventory of patients, allowing resources' transfers, at each hospital within the studied time horizon. Puerto Montt's hospital inventory is represented in orange, Calbuco's in gray and Frutillar's in yellow.

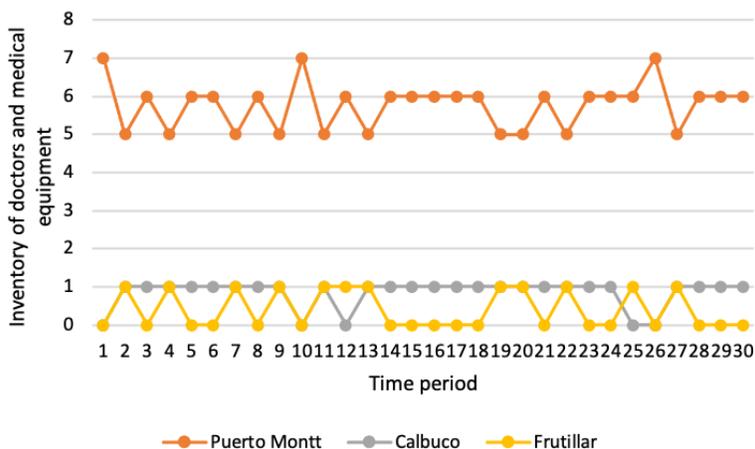


Figure 4. Inventory of doctors and medical equipment, allowing resources' transfers, at each hospital within the studied time horizon. Puerto Montt's hospital inventory is represented in orange, Calbuco's in gray and Frutillar's in yellow.

### 5.4 Proposed Improvements

This research focuses on studying a specific case study in the Zona del Reloncaví, with three hospitals and one specialty. However, the implications and benefits that the application of this concept of transfer of doctors and medical equipment in healthcare can bring, invite to extrapolate this work to situations even closer to the reality of the system, in terms of the following features.

Regarding the model:

- Considering the over-demand that may exist in the system, to which the proposed CHRMM responds by concentrating the supply of doctors and machines in Puerto Montt' hospital, it is proposed to impose a minimum number of doctors and machines per hospital.
- Since the model incorporates the flow of doctors in aggregated terms, it is proposed to disaggregate the analysis of transfers, with the objective of imposing, for example, a maximum number of transfers per doctor in the studied period.

- It is recommended to get rid of the assumption that transfers of patients, doctors and medical equipment take a full day, and to incorporate vehicle routing as a mechanism to add more realism to the model.

- It can be complemented by conducting a study from the point of view of cost reduction, i.e., from a hospital approach, to analyze the economic feasibility of implementing this concept in Chile.

Regarding the experiments:

- The modeling network may incorporate in the future the total number of hospitals in the Zona del Reloncaví, allowing a closer analysis to the reality of the sector, although it will increase the execution time of the code.

- More specialties could be considered, along with different types of medical equipment for each one.

## 6. Conclusions

This paper reports the results obtained by analyzing the consequences of allowing transfers of doctors and medical equipment within a hospital network. It should be noted that the objectives of the study are met. On one side, it is concluded that the implementation of a CHRMM in the studied health network is feasible. Also, the performance of the proposal is measured, showing, mainly, that it brings benefits by increasing both the level of service offered by the hospitals involved and the spatial accessibility offered to patients, having a major implication in a significant reduction in patients' transfers. Thus, the implementation of this CHRMM strategy would be positive for the inhabitants who are treated in the selected hospital network and could have a great impact on their daily lives.

From the results, it is suggested the active participation of the Government of Chile when addressing the poor spatial accessibility to healthcare that mainly affects rural areas located far away from big cities. The latter could be tackled by injecting resources within the framework of the IHSN Program. By doing so, the resources invested by the Chilean Government would be oriented to the implementation of a new health system according to the new needs of the 21st century, based on a collaborative economy where transfers of doctors and medical equipment are allowed.

Besides, it is concluded that it would be beneficial to further develop this scheme. Therefore, the next step would be to develop a prototype applicable to a network of hospitals in the country, in order to analyze, on-site, the benefits expected from this research. The authors recommend analyzing the results of the COVID-19 Vaccination Program in Chile, given that its implementation in regions has been based on the application of a resource management model similar to the one proposed.

Finally, in the medium term, a public policy should be developed, linked to an IT program that would allow hospitals to request and offer their own medical equipment, to achieve a higher level of service and, above all, greater spatial accessibility, in terms of reducing socio-territorial inequalities in relation to health services.

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## Biographies

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**Macarena Navarro** is an undergraduate student of the Industrial and Systems Engineering Department at Pontificia Universidad Católica de Chile (PUC). She is currently a Data Science intern at i-DUX, where she is working with Machine Learning models. Macarena has been teaching assistant of many Operations Research and Logistics related courses at PUC. She was the vice-president of the Industrial and Systems Engineering Student Chapter, and the Project Coordinator of the Teaching Assistants' body of her university. In 2020, Macarena was recognized with the INFORMS

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